NASA TECHNICAL TRANSLATION

NASA TT F-13,849

EOLE BALLOON SENSORS:

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Translation of "Capteurs 'EOLE Balloons': Resume des Essais Realises en 'Phase Prototypes' sur les Capteurs de Pression, Supression et Temperature de la Nacelle EOLE," Bretigny, Centre National Space d'Etudes Spatial, Jan. 14, 1971. (No. 71/893/CT/TE/EG/EOLE/B) 14 Pages.

N72-14460 (NASA-TT-F-13849) EOLE BALLOON SENSORS J.S. Boutemy (Techtran Corp.) Feb. 1971 14 P CSCL 14B G3/14

Unclas 12092

(CATEGORY)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 FEBRUARY 1971

EOLE BALLOON SENSORS:

Summary of Tests Conducted at the Prototype Phase on Pressure, Overpressure and Temperature Sensors in the EOLE Capsule

J. C. Boutemy

The total weight of the regulator will be less than 40 grams.

Markings:

The regulator will be labeled visibly with the following identification marks: /1*

-- builder's label

-- CNES label

-- serial number.

VII. Aerial Safety:

1. Each individual component will have a mass less than 3 grams.

2. The mass ratio of the regulator in the vertical section must be less than $2g/cm^2$.

3. The mass ratio of the regulator with respect to height must be less than 5g/cm.

4. Choice of materials: the mechanical parts fused for connection to the capsule should preferably be made of Delrin or PPO or Mostaform C.

VIII. Reliability:

The material must satisfy the following conditions of reliability:

-- probability of proper function greater than 90% for operation under flight conditions for 3 months.

*Numbers in the column indicate pagination in the foreign text.

IX. Environmental Specifications:

The material must be able to withstand the following different environmental conditions:

1. Storage Conditions:

1.1. Storage at the Plant:

Storage is defined on the basis of instructions.

SUMMARY /2

This note contains a brief summary of the different tests which were performed at the prototype stage before the launching of a series of 600 atmospheric pressure sensors, inflation of the balloon envelope, and ambient air pressures for the EOLE experiment.

The following chapters are particularly important:

I. STUDIES CONDUCTED AT THE FACTORY ON THE PROTOTYPE STAGE

II. GENERAL DESCRIPTION OF SENSORS

III. HANDLING OF TECHNICAL PROBLEMS

IV. ELECTRIC AND CLIMATIC TESTS

V. THERMISTOR TESTING

VI. TIGHTNESS TESTS

VII. MECHANICAL TESTS

VIII. FLIGHT TESTS

IX. TESTS OF ELECTRICAL INTEGRITY

X. OPTICAL CHECK

XI. AERIAL SAFETY TESTS

XII. TESTS STILL TO BE PERFORMED

I. STUDIES CONDUCTED AT THE FACTORY ON THE PROTOTYPE STAGE /3

Pressure and Overpressure Sensors

C.N.E.S. issue contract 69 CNES 571 (dated July 15, 1969) to the Crouzet Company for the study and manufacture of the following models:

-- 5 electrical models
-- 10 mechanical models
-- 20 prototypes

for each type of sensor (pressure and overpressure).

The technical specifications are given in note 175/EOLE/B.

Temperature Sensors

The C.N.E.S. issue contract 69 CNES 606 (dated October 13, 1969) to the Sintra Firm for the study and manufacture of the following models:

-- 10 electrical models
-- 20 mechanical models
-- 40 prototypes.

The technical specifications are given note 182/EOLE/B.

Integration of Sensors

The sensors were necessarily installed far from the capsule (with approximately 3 m between the overpressure sensor and the temperature sensor).

In order to simplify the final integration at the station, it was decided to make a "sensor group" linked to the capsule by a single connector.

Initially, the C.N.E.S. envisaged the manufacture of a flexible printed circuit to act as a connector, consisting of a strip of Mylar or metallized capton, 30 mm wide and 3 m long. For practical, technological and financial reasons, this solution was abandoned in January 1970 for a more classical arrangement using a shielded cable weighing 16 grams per meter.

The Crouzet Firm was then entrusted with studying the harmonious integration of the three sensors with an eye toward mass production. The first models were available in June 1970.

Tests of aerial security which were conducted October 1970 led up us to make certain modifications which were included in the definitive models made in January 1971.

II. GENERAL DESCRIPTION OF SENSORS

Pressure and Overpressure

The latter are composed primarily of a manometric capsule made of 5 elementary corrugations of hammer-hardened Durinval B. The displacement sensor consisted of a ferrite pot with a variable air gap (function of the displacement of the membrane), connected to a LC oscillator. The analyzing circuits consist simply of a power supply, the oscillator, a bistable oscillator and an impedance matching stage.

The technology employs a classical printed circuit and discrete components.

The assembly is contained inside an A5 box (0.2 mm thick), rectangular in shape, with a square base 35 mm on the side and 110 mm tall).

The pressure sensor is linked electrically to the capsule by a 7-contact connector and receives mechanical and electrical sensors from the temperature sensor. The connection between the pressure and overpressure sensors is provided by a Filotex cable 3 mm long containing 4 conductors and a shield.

The explosive rivet is connected to the overpressure sensor by 2 Jiffy type connectors.

Temperature Sensor /5

The electronic circuitry uses thin-film technology, with an LID glass substrate and miniature capacitors. It is integrated in two T 08 cabinets; one for the stabilized power supply; the other for the oscillerator and output adaptor.

The measuring thermistor is a type 31 A 401 C (Victory); it is 125 microns in diameter. It is mounted on a perforated glass plate, 0.3 mm thick. This sensor plate was approved by Professor Morel after a series of flight tests. It contains 3 "thin-film" resistances which linearize the transfer function of the thermistor in the useful range (-80°C, -30°C).

This plate is attached to the electronic section by a tube (AG 3) 1 m long and 5.6 mm in diameter. This arm, tilted at 35° to the horizontal, makes it possible to place the thermistor simultaneously at a distance from the axis of the capsule and from the battery heater, thus avoiding any disturbance of the temperature measurement.

The complete "sensor group" weighs approximately 200 grams.

III. HANDLING OF TECHNICAL PROBLEMS IN THE PROTOTYPE STAGE /6

Pressure and Overpressure Sensors

The principal disability was of a mechanical and metallurgical nature; it involved, on the one hand, the manufacture of perfectly tight seams on the sides of the capsule and on the other hand of obtaining the smallest possible total expansion coefficient.

The prototype capsules were made by arc soldering in an argon atmosphere according to the TIG process. The thinness of the sides to be soldered (0.08 mm) by this method made it extremely difficult to obtain acceptable quality.

The Crouzet Company improved the quality of the capsules considerably by using a semiautomatic soldering bench with a micro-plasma arc (Secheron Plasma Fix 40). This bench is operational and can be used for mass production (15,000 welds to be made).

Temperature Sensors

The Sintra Firm initially suggested a "thin-film" technique with direct connection of the transistor assembly on the substrate. Difficulties were encountered, on the one hand, in obtaining lots of assembly that were sufficiently homogeneous and of good quality and on the other hand in regard to the mounting of these elements on the substrate. With the permission of C.N.E.S., Sintra adopted an intermediate technology consisting of the direct application of LID or a preliminary assembly in mobytab, which allows electrical control of the components mounted on the substrate. Electronics of the temperature sensor necessitate slight dissipations in the components and quite often a pairing of the transistors. This technology was developed in the 40 prototypes and will be used for mass production.

IV. ELECTRICAL AND CLIMATIC TESTS /7

A. Pressure and Overpressure Sensor

Function in Pulsed Mode

Stability of the output frequency is assured in the pulsed mode; measurement was made between 400 and 600 ms after the powering of the sensors.

The pressure sensors are quite stable about 20 ms after they have been subjected to a potential.

Output Level

The pressure sensors can withstand without frequency variation the charge developed by a 1,000 pf capacitor in parallel with a type 54 L logic gate.

Fidelity of Pressure Measurement

Some of the capsules (20%) showed a hysteris defect extending from 0.1 mb to 0.2 mb. This defect was far below the admissible tolerance (± 2 mb) and will probably be improved by the mass produced sensors.

Temperature Variations

This is the most difficult performance to maintain. While the admissible tolerance is 4 mb for the same pressure at -60°C and +30°C, a statistical analysis made of 40 sensors showed that 82% of them have a derivative between these two temperatures, that is, between 2 and 4 mb, and 10% of the sensors have a higher derivative (see the hystogram).

Theoretically, the electronics requires a control that will allow compensation of the residual thermal derivative of the measurement capsule. The manufacturer asserts that in series production the capsules will be more homogeneous and their temperature derivatives will be less diverse.

Influence of Attitudes /8

An inclination of 30° relative to flight position introduces an error of less than 0.1 mb in the measurement of pressure (or overpressure).

Climatic Tests

For 11 consecutive days, 20 sensors were subjected to the EOLE cycles specified in the contract (-60°C, -70°C, -30°C, +30°C).

A comparative statistical analysis of the results obtained with more than 150 measurements conducted at -60°C, -30°C and +30°C before and after the endurance tests show (see the hystogram) a significant decline in performance. In fact, the number of points differing by more than 2 mb from the calibrated value changes from 7% of the measurement points to 15%.

This apparent degradation actually is the result of a generally weak evolution of the capsule under the influence of the climatic cycles. An evolution limited to 0.1 or 0.2 mb can cause a large number of measurement points for exterior temperatures to exceed the tolerances, with the amplitude of the derivatives being correct outside the specifications.

In parallel with this effort to reduce the amplitude of the derivatives with regard to temperature, it is expected that the mass produced equipment will have a supplementary stabilization of the manometric capsules.

No breakdowns were recorded either in the electrical or climatic tests.

B. Temperature Sensors /9

Function in Pulsed Mode

The frequency stability was correct beginning 100 ms after application of potential.

The power supply section was subjected to a minor modification during the prototype phase, aimed at a correct function of the sensors regardless of the rise time of the power signal.

Output Level

The output impedance was largely adjusted to the specified charge.

Measurement Fidelity

The factory calibration was performed in a freon bath before complete assembly of the sensors. Recalibrations were made at the C.N.E.S. using an

apparatus which would allow measurement in air with a temperature homogeneity better than 0.1°C. Measurements in this fashion differ less than 0.3°C from the calibration measurements.

The first prototypes showed a degradation of the linearization resistances located on the sensor plate. The following prototypes were covered with a protective varnish.

Temperature Derivatives

The error in the sensor produced by heating of the analyzer electronics by 50°C relative to the thermistor was generally less than 0.5°C (specification: ± 1.2°C).

Climatic Tests

Fourteen temperature sensors were subjected to EOLE cycles (-60°C, -70°C, -30°C, +30°C) at 200 mb for 11 consecutive days.

No systematic derivation of the calibration curves was found.

One breakdown took place during the cycles, caused by the failure of a /10
transistor (2 N 2222).

A breakdown occurred in another lot during a calibration test, caused by the breaking of a connection in a capacitor assembly.

V. QUALIFICATION OF THE THERMISTOR

A very severe program was applied to a lot of 125 thermistors, with an eye toward revealing possible aging of this component under different conditions.

The test lasted one year. The synthesis has still not been completed, but it does not appear a priori that there is any defect that would endanger the temperature measurements in the EOLE program.

VI. TIGHTNESS TESTS

The Crouzet Company made a special study of the tightness of the connections of the pressure sensor on the plug of the balloon. These tests ended with definition of the assembly sections and their tolerances. Tightness was perfect ($< 0.3 10^{-8}$ cm^3/sec) at both +20°C and -70°C.

The total tightness of each overpressure sensor in the series will be tested individually at +20°C and at -70°C with sampling.

VII. MECHANICAL TESTS /11

Each sensor is sufficiently sturdy to withstand four falls for a distance of 10 cm on each face on to a hard metal surface without damage.

P, Δ P Sensor

The test was conducted systematically on the 40 prototypes. One of them showed a change in calibration due to mechanical variation.

Θ [Temperature] Sensor

For ease in checking calibration, the prototype sensors carried a rigid sensor housing in an arm 50 cm long, which is very unfavorable from a mechanical standpoint.

Additional mechanical models made it possible to achieve effective protection of the sensor against shock. The mass produced sensors will maintain this individual protection until the moment the balloon is launched in order to protect the sensor simultaneously against shock and dust. (The cleanliness of the glass plate has a direct influence on the sensitivity of the sensor to solar radiation).

VIII. FLIGHT TESTS

P and Δ P Sensor

Six prototype sensors are to be launched in the flight tests to take place in April 1971.

We recall that the type EOLE sensors are derived from the Ghost type sensors which were made at the same factory. The latter sensors have been flying for several years now.

Θ Sensors

Flight tests involving 10 prototype sensors were performed in September 1970 at Mendoza. The purpose of this test was to determine the mechanical configuration of the arm. Several lengths were tested. The complete report will be the

subject of a later report. The results were judged satisfactory with an arm 1 m long, tilted at 35° to the horizontal.

IX. TESTS OF ELECTRICAL INTEGRATION /12

The compatability between the sensor group and the electronic capsule was tested in May 1970 and no problem was found.

In the course of these tests, we verified (for example) that the measurement signals delivered by the three sensors were insensitive to antenna radiation.

X. OPTICAL CHECK

Several optical measurements that were performed on the samples of the sensor housings indicated that the temperature of the housing that was chosen would be a maximum of -2°C for an albedo of 0.35 and a maximum of +8.5°C for an albedo of 0.8; the ambient temperature is assumed to the -40°C.

XI. TESTS OF AERIAL SECURITY

Two types of tests were performed: firing a subassembly from a cannon at a fixed pane of glass, and swinging a pane of glass at 280 m/sec against the assembled sensors on the capsule in flight position.

The tests were performed on the first sensors which had a housing made of fiberglass. Despite this concentration of mass at the waist of the manometric capsule, the impact was withstood and the glass was subjected only to minor damage.

Other tests performed in October 1970 with new sensors in metal housings were less favorable. The problem was studied again by the C.N.E.S. and the Crouzet Company, and new tests are to be made in January 1971 with very good chances of success.

The temperature sensor located in the most unfavorable place as far as configuration is concerned (axis of the sensor arm) did not suffer any damage.

XII. TESTS STILL TO BE PERFORMED /13

The following are planned for the phase to precede mass production:

-- checking of the packing of the sensor groups.

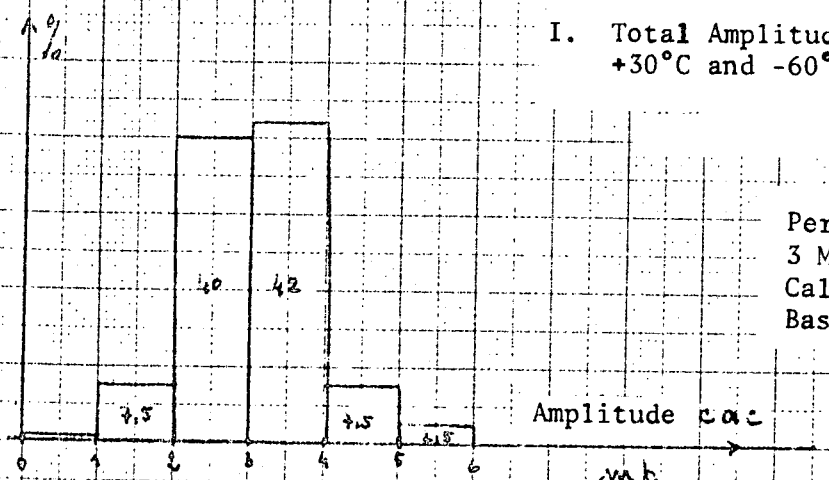
The tests are planned for March 1971 and it will involve checks of the vibrating pot and actual tests on the landing strip, with the sensors being conditioned in the packing plan for the series.

Flight on the Platform of the EOLE Capsule

The tests of the drive platform of the mass produced capsules (June 1971) will be taken advantage of to record the maximum information from the sensors during flight on the platform (1 to 3 hours).

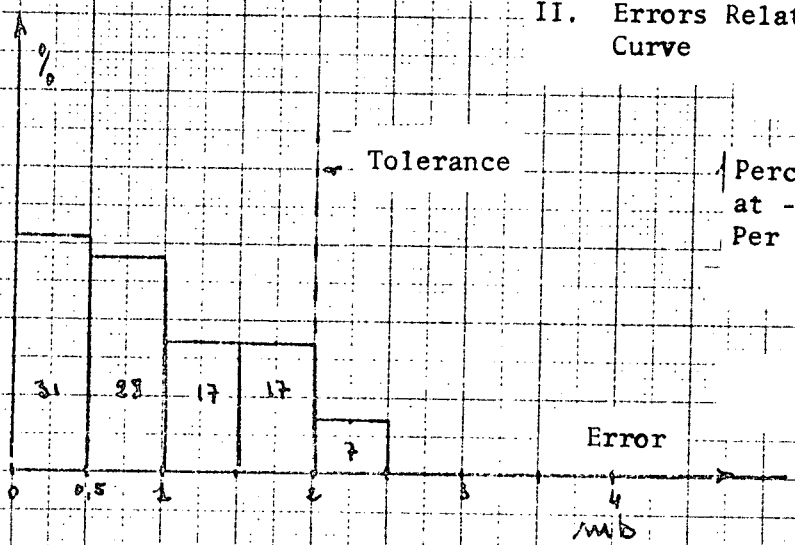
The measurement accuracy and the amount of information that can possibly be gathered will be definitely greater than that of the flight test at Mendoza (September 1971); these measurements will make it possible to check the absence of thermal disturbances caused by the capsule.

I. Total Amplitude of Derivatives Between +30°C and -60°C (Numbers in mb)



Percentage on 40 Sensors and 3 Measurement Points Using a Calibration Curve and On the Basis of Temperature

II. Errors Relative to the Calibration Curve

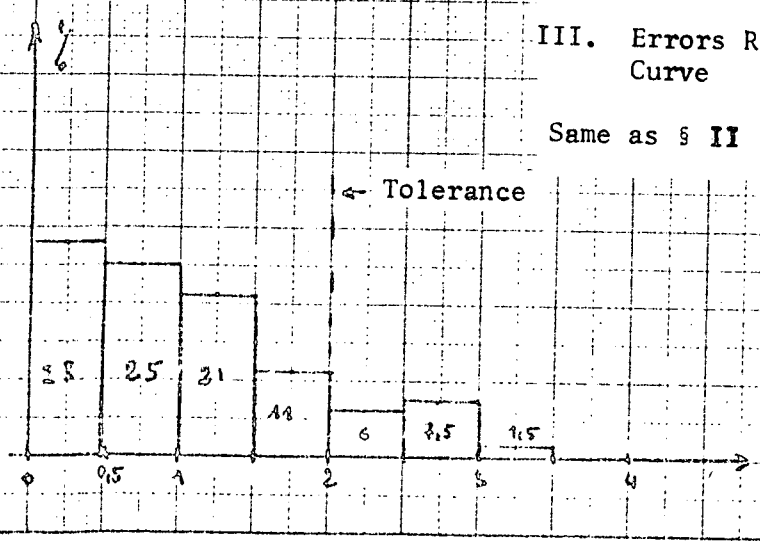


Percentage of Measurement Points at -60°C, -30°C, +30°C (3 Points Per Sensor at Each Temperature)

After Storage for 1 Month

III. Errors Relative to the Calibration Curve

Same as § II



After Storage for 5 Months and 10 EOLE Cycles

Translated for the National Aeronautics and Space Administration under contract No. NASw-2037 by Techtran Corporation, P. O. Box 729, Glen Burnie, Maryland, 21061.